REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE 4/25/97	3. REPORT TYPE AND DATES COVERED Final Report/ 04/01/92-09/30/94

4. TITLE AND SUBTITLE Analysis of Soviet Microstructure Data	5. FUNDING NUMBERS N00014-92-J-1424
6. AUTHOR(S) Carl H. Gibson	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of California, San Diego 9500 Gilman Drive La Jolla, CA 92093-0411	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Administrative Grants Officer Office of Naval Research 4520 Executive Drive San Diego, CA 92121-3019	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT DISTRIBUTION STATEMENT A Approved for public release Distribution Unlimited	12b. DISTRIBUTION CODE

19970602 102

13. ABSTRACT (Maximum 200 words)

To develop quantitative means (hydrodynamic diagrams) to determine the hydrodynamic state of microstructure patches in stratified and rotating flows such as the ocean; that is, whether the patches represent active turbulence, active-fossil turbulence, or completely fossil turbulence. A precise definition of turbulence has been proposed that shows the direction of the turbulence cascade usually assumed is incorrect. The Reynolds rules of averaging postulates of 1894 used in dissipation flux balances such as the Osborn and Cox (1972) equation K=DC are re-examined by a control volume averaging technique in Gibson (JGR Nov.1991), that reveals the need for averaging over very large data sets, with length scales larger than the largest turbulence scales in either the horizontal or vertical.

14. SUBJECT TERMS Towed body, dropsonde microstructure, temperature dissipation rates, ocean turbulence, turbulence fossilization, and fossil turbulence waves.	15. NUMBER OF PAGES 6
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)

DTIC QUALITY INSPECTED 1

FINAL REPORT

N00014-92-J-1424

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Analysis of Soviet Microstructure Data

Research Goals:

The ultimate goal is to acquire a better understanding of stratified and rotating turbulence and mixing processes so that measurements of ocean microstructure, mesostructure and other variables can be used to make reliable inferences about vertical fluxes of heat, mass, and momentum.

Objectives:

The near term objectives are to continue to analyze, interpret, and publish sensor characteristics and measurement results from towed body and dropsonde microstructure and fine structure data collected during the 51st Cruise of the R/V AKADEMIK KURCHATOV, a Research Vessel of the Shirshov Institute of Oceanology, Academy of Sciences of the (former) USSR (IOAN). In addition, other data sets collected in FSU cruises and expeditions will be identified, evaluated, and processed, in collaboration with various scientists of the FSU. Temperature dissipation rates in the California coastal upwelling region were found to be precisely lognormal averaged over a wide range of averaging scales, with an intermittency constant close to values reported in the atmosphere and interstellar medium, as reported in Gibson (Proc. Roy. Soc. 1991). Similar statistical tests have been made by Lozovatsky and Erofeev in other regions from the towed body GRIF, and give rather different results when the range of the mixing cascade is attenuated. The role of island wakes in vertical mass, heat, and momentum transport in equatorial regions can be evaluated from the dropsonde and towed body data colected during AK51. Statistical properties of mixing and turbulent activity coefficients will also be studied, and compared to results in Gibson, Nabatov and Ozmidov (1993). Unique microstructure sensor systems developed in the FSU need to be identified, tested, and intercompared with each other and Western sensors. For example, Prandke and his colleagues at Rostock-Warnemunde have developed a shear probe with

much better strength, sensitivity, and spatial resolution than those used in the West with which he and Stips have identified Baltic microstructure as mostly fossilized remnants of previous turbulence activity. The probe is routinely stabbed into the bottom without harm.

Approach:

The approach has been to continue the good relationship with Soviet ocean turbulence experts that has been on going since 1972. The first microstructure intercomparison cruise was on the 11th Cruise of the DMITRI MENDELEEV in 1974 with Schedvin and Deaton, and Ozmidov, Paka, Lozovatsky, Nabatov and others of IOAN Moscow and Kaliningrad, in which Schedvin (1977) measurements gave the first decisive evidence of fossil temperature turbulence, forming the basis of the Gibson (1980) fossil turbulence model. Such scalar remnants are much more persistent than the fleeting active turbulence events that produce them, and preserve information that can be used with proper modeling to make more reliable estimates of average dissipation rates and vertical fluxes. Estimates that ignore or dispute the turbulence fossilization phenomena are subject to truly egregious undersampling errors, typically underestimating true average dissipation and flux values by factors of one to five orders of magnitude. Most Western microstructure studies have taken this latter approach, and have attempted to solve the intermittency problem by collecting enormous numbers of dropsonde samples. Unfortunately, most of these are from the same region, and lack independence. Fortunately, excellent evidence of the turbulence fossilization process has accumulated, and evidence of a new crucially important phenomena, termed "fossil turbulence waves" by Gibson (JGR, Nov. 1991), have emerged.

Tasks Completed:

Publication of ideas about fossil turbulence in Western oceanographic journals has been a difficult task. One reason has been that active turbulence patches are so rare in the ocean that many published data sets contain no examples with AT > 1, where completely active turbulence is identified as a patch with viscus dissipation epsilon larger than epsilon sub 0 equal either 13DCN^2 or 3L^2N^3 from Gibson (1980) at the buoyancy-inertial transition (critical Froude number) where fossilization begins, where L is the maximum vertical density overturn scale, D is the molecular diffusivity of the scalar field, C is the Cox number, and N is the ambient Vaisala frequency of the patch, and AT = (eps/eps0)^1/2 is the turbulence activity parameter of Gibson (1980). How is it possible to measure thousands of microstructure patches and rarely see one with AT > 1? The answer is that it is not possible, and numerous patches in the ocean have been detected with AT > 1. To find many patches with AT > 1, measurements near an ocean turbulence source are needed, and these were supplied by the dropsonde BAKLAN measurements of Nabatov and Ozmidov near Ampere Seamount. The results are shown in the attached hydrodynamic phase diagram. A patch in the Arcticin the completely active state has finally been reported, by Wijesekera and Dillon (1997), the first ever except for the Ampere Seamount results of Gibson, Ozmidov and Nabatov(1993).

Scientific Results:

Data analysis from AK51 continues, with results given in a number of publications and works in progress listed previously. An overall view of currents, shear, and stratifications for the dateline Pacific equatorial undercurrent, with typical microstructure patterns, are reported in Lilover et al. (1993). AT and temperature dissipation rate values in the surface (Western) and subsurface (Eastern) wakes of Baker and Howland islands have been recently computed by Lozovatsky and Erofeev, and are being evaluated. Preliminary sensor tests by Baker will be published in Gibson, Nabatov, and Ozmidov (DAO 1993).

Accomplishments:

Probably the most important accomplishment of this work has been to develop quantitative means (hydrodynamic phase diagrams) to determine the hydrodynamic state of microstructure patches in stratified and rotating flows such as the ocean; that is, whether the patches represent active turbulence, active-fossil turbulence, or completely fossil turbulence. A precise definition of turbulence has been proposed that shows the direction of the turbulence cascade usually assumed is incorrect. The Reynolds rules of averaging postulates of 1894 used in dissipation flux balances such as the Osborn and Cox (1972) equation K=DC are re-examined by a control volume averaging technique in Gibson (JGR Nov. 1991), that reveals the need for averaging over very large data sets, with length scales larger than the largest turbulence scales in either the horizontal or vertical.

ONR-Sponsored Publications

P-Gibson, C. H. 1991: Laboratory, numerical, and oceanic fossil turbulence in rotating and stratified flows. J. Geophys. Res., 96 (C7), 12,549-12,566.

P-Gibson, C. H. 1991: Kolmogorov similarity hypotheses for scalar fields: Sampling intermittent turbulent mixing in the ocean and galaxy. Turbulence and stochastic processes: Kolmogorov's ideas 50 years on, Proc. Roy. Soc. Lond. A, 433 (no. 1890), 149-164.

P-Gibson, C. H. 1991: Turbulence, mixing, and heat flux in the ocean main thermocline, J. Geophys. Res., 96 (C11), 20,403-20,420.

P-Gibson, C. H. 1991: Introduction to Scalar and Stratified Flows, in Turbulent Shear Flows, 7, edited by F. Durst and W. C. Reynolds, Springer-Verlag, Berlin, 3-7.

P-Gibson, C. H. 1991: Fossil two-dimensional turbulence in the ocean, in Turbulent Shear Flows, 7, edited by F. Durst and W. C. Reynolds, Springer-Verlag, Berlin, 63P

P-Gibson, C. H., V. Nabatov, and R. Ozmidov 1993: Measurements of turbulence and fossil turbulence near Ampere seamount, Dynamics of the Atmosphere and Ocean, 19, 175-204.

PS-Gibson, C. H. and J. Imberger 1993: Formation of turbulence on a tilted density interface, submitted to J. Fluid Mechanics.

P-Lozovatsky, I. D., A. S. Ksenofontov, A. Yu. Erofeev, and C. H. Gibson 1993: Modelling of the Evolution of Vertical Structure in the Upper Ocean by Atmospheric Forcing and Intermittent Turbulence in the Picnocline, J. Marine Systems, 4: 2-3, 263-273.

P-Lilover, M. J., I. D. Lozovatsky, C. H. Gibson, and V. Nabatov 1993: Turbulence Exchange Through the Equatorial Undercurrent Core of the Central Pacific, J. Marine Systems, 4: 2-3, 183-195.

P-Gibson, C. H., 1996: Turbulence in the ocean, atmosphere, galaxy, and universe, Applied Mechanics Reviews, 49:5, 299-315.

PI-Korchagin, N., I. Lozovatsky, and C. H. Gibson 1993: Temperature and salinity layered structure statistics in a Meddy near a seamount, in preparation, J. Geophys. Res.

PI-Gibson, C. H. 1993: Turbulence in Stratified Flow, book, for Johns Hopkins University Press.

C-Gibson, C. H. 1992: Fossil Turbulence Waves and Ocean Mixing, International Session on "Meso- and Microstructure of the Ocean--Measurements and Models of Processes", Sixth Annual Workshop on "Laboratory modelling of dynamic processes in the ocean" of the Commission on the problems of the world ocean of the Russian Academy of Sciences, St. Petersburgh, September
8-12, 1992.

C-Gibson, C. H. 1992: Turbulence: What is it, and which way does it cascade? 45th Annual Meeting, Division of Fluid Dynamics, November 22-24, 1992, Florida State University-Florida A&M University, Tallahassee, Florida.

C-Lozovatsky, I. D. and C. H. Gibson 1992: Statistics of Parameters Controlling Vertical Mixing in the Picnocline, C.S. Cox Symposium, AGU Fall Meeting, Dec. 10, 1992, San Francisco, CA.

C-Gibson, C. H. 1992: Cox Numbers, Fossil Turbulence, and Ocean Mixing, C.S. Cox Symposium, AGU Fall

Meeting, Dec. 11, 1992, San Francisco, CA.

Statistics

9 Papers published, refereed journals
4 Papers submitted, refereed journals
0 Books or chapters published, refereed publication
0 Books or chapters submitted, refereed publication

1 Invited presentations
4 Contributed presentations
0 Technical reports and papers, non-refereed journals
0 Undergraduate students supported
0 Graduate students supported
0 Post-docs supported
0 Other professional personnel supported

EEO/Minority Support
0 Female grad students
0 Minority grad students
0 Asian grad students
0 Female post-docs
0 Minority post-docs
0 Asian post-docs

Patents and awards:

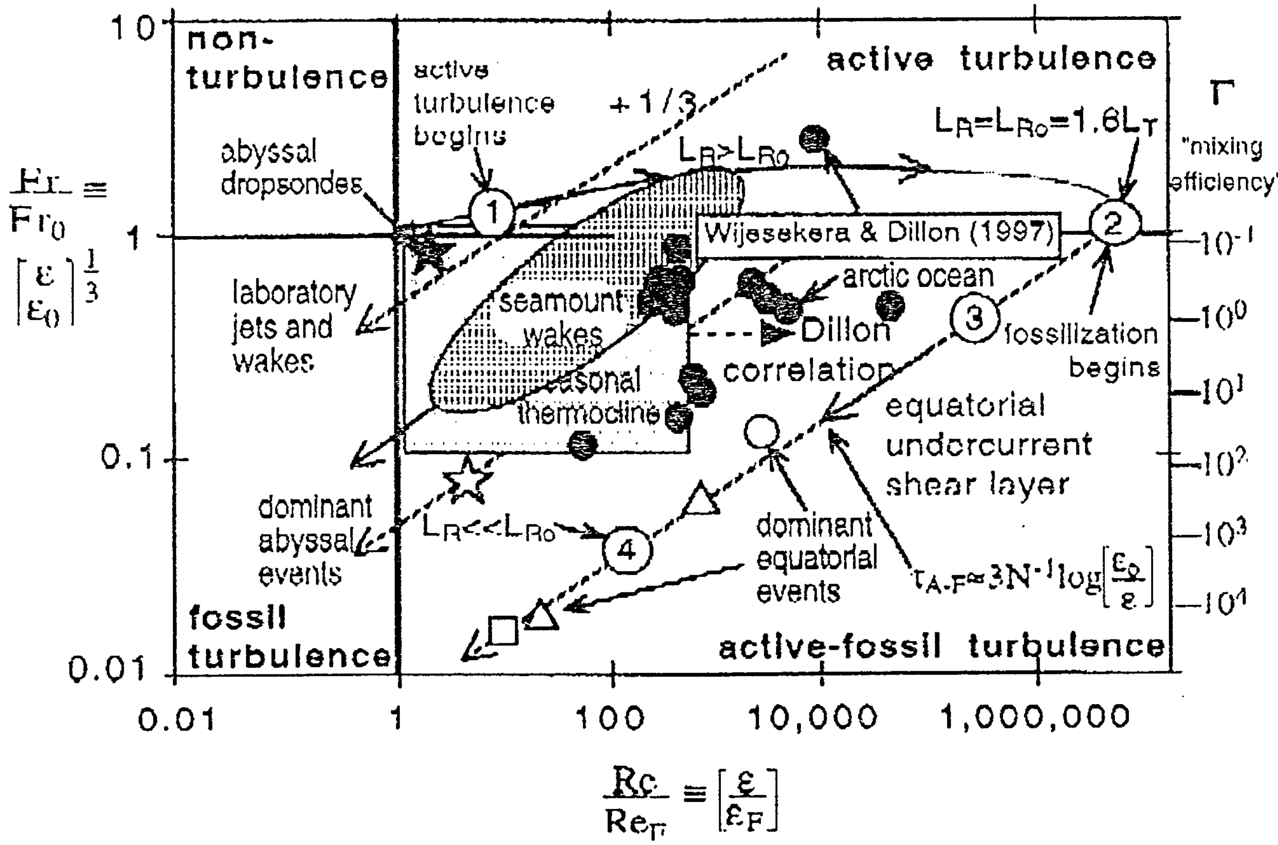
Influences:

The most influential books were Landau and Lifshits; Fluid Mechanics, and Phillips; The Dynamics of the Upper Ocean.

The most influential papers were:Hebert, D., J. N. Moum, C. A. Paulson, and D. R. Caldwell, Turbulence from internal waves at the equator, Part II: Details of a single event. J. Phys. Oceanogr., 22, 11, 1346-1356, 1992.

Moum, J. N., D. Hebert, C. A. Paulson, and D. R. Caldwell, Turbulence from internal waves at the equator, Part I: Statistics. J. Phys. Oceanogr., 22, 11, 1330-1345, 1992.

Gregg, M. C., Variations in the intensity of small-scale mixing in the main thermocline. J. Phys. Oceanogr. 7, 436-454, 1977.



non-turbulence
active turbulence begins
+1/3
active turbulence
Γ
"mixing efficiency"
$L_R = L_{Ro} = 1.6 L_T$
abyssal dropsondes
$L_R > L_{Ro}$
$\frac{Fr}{Fr_0} \equiv \left[\frac{\varepsilon}{\varepsilon_0}\right]^{\frac{1}{3}}$
Wijesekera & Dillon (1997)
arctic ocean
laboratory jets and wakes
seamount wakes
Dillon correlation
fossilization begins
seasonal thermocline
equatorial undercurrent shear layer
dominant abyssal events
$L_R << L_{Ro}$
dominant equatorial events
$\tau_{A-F} \approx 3N^{-1}\log\left[\frac{\varepsilon_o}{\varepsilon}\right]$
fossil turbulence
active-fossil turbulence
10
1
0.1
0.01
0.01
1
100
10,000
1,000,000
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
$\frac{Re}{Re_F} \equiv \left[\frac{\varepsilon}{\varepsilon_F}\right]$